

# ENVIRONMENTAL PROTECTION

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## THE USE OF EXCESS ACTIVATED SLUDGE FROM MUNICIPAL SEWAGE TREATMENT WORKS IN PRODUCTION OF CONSTRUCTION CERAMICS

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The composition of a ceramic mixture for production of brick using excess activated sludge from municipal sewage treatment works is developed. The properties of the samples obtained meet the requirements imposed on ceramic construction products. Assessment of the environmental safety of the suggested material was carried out and the efficiency of utilization of activated sludge in production of construction materials was demonstrated.

Biological oxidation is a method widely used in practice for purification of household and industrial sewage and a necessary link in the treatment of contaminated water before it passes into natural water bodies. The essence of biological purification treatment consists in the fact that dissolved organic compounds are consumed by microorganisms. Part of these compounds is oxidized and the other part is transformed into biomass. The latter causes an increase in activated sludge, and as a result, an excessive amount of sludge is formed.

The share of excess activated sludge (EAS) in sewage precipitate comprises 60–70%. The amount of excess activated sludge accumulated in the Belarusian Republic comprises 1.5 million tons (calculated for dry matter, moisture of 96–98%), and this volume keeps growing. The annual increase in activated sludge in the world is enormous. Just in Western Europe it comprises about 5.5 million tons. According to the data of VNIIVODGEO, every year nearly 3.5 million tons of activated sludge biomass is formed in the CIS countries [1]. Considering the large scale of waste accumulation from biological treatment of sewage, as well as the heavy metals and pathogenic microorganisms contained in this waste, the development of a scientifically sound approach to utilization of this kind of waste is extremely urgent.

The most common method of EAS utilization is its use in agriculture as fertilizers and fodder additives. It is conditioned by the substantial content of biogenic elements (phos-

phorus, nitrogen, potassium) in activated sludge. Activated sludge has many more nutrient components than precipitate from primary settling tanks, namely, 5–6% nitrogen and 4–7% phosphorus related to dry mass. The fertilizing value of EAS is close to that of manure. Activated sludge introduced in soil contributes to an increase in the productivity of crops and improvement of crop quality. Some data indicate that activated sludge is more efficient than mineral fertilizers. It is preferable to use it for heavy humus soil that has a high absorbing capacity [2, 3].

However, application of EAS in agriculture is restricted by its content of heavy metals which can subsequently cause accumulation of these metals in plants and animal tissues. Therefore, utilization of municipal sewage EAS containing heavy metals in agriculture is impossible.

The studies in [4, 5] suggest using activated sludge as an additive to electric power plant fuel or directly in fuel production. EAS can be used as a flocculant, a filler for paper stock composition in production of pasteboard from unbleached intermediate products, in plastic production, as well as processing of EAS into sorbents [6–8]. However, all variants suggested do not exclude the possibility of dissipation of heavy metals contained in EAS in the environment (for example, in fuel combustion), do not guarantee the environmental safety of the end product (plastics, pasteboard, paper), or implementation of these suggestions is only possible if heavy metals are absent in EAS (production of flocculants and sorbents).

That is why a promising line of investigation is utilization of EAS in production of construction materials, since

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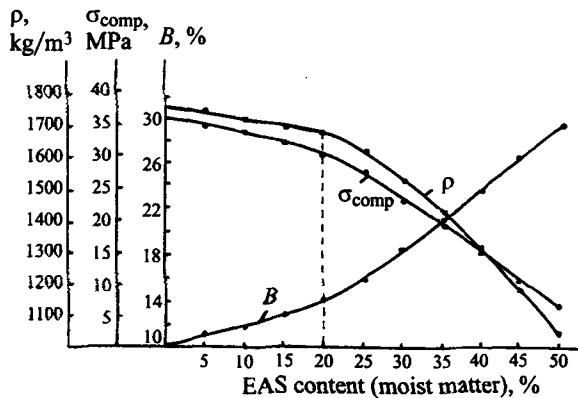


Fig. 1. Dependence of water absorption  $B$ , density  $\rho$ , and compressive strength  $\sigma_{comp}$  of samples on EAS content.

these products undergo high-temperature treatment, as a result of which heavy metals are transformed into high-strength compounds (silicates and aluminosilicates). Therefore, it is possible to obtain high-quality, environmentally safe products. However, there are few studies dedicated to the utilization of excess activated sludge in the building materials industry. The studies in [9, 10] suggest using EAS after its decontamination as an additive in production of cement, concrete, and gypsum concrete. The study in [11] investigates the effect of sludge additives on the properties of ceramic mixtures at high temperatures. It is established that introduction of sludge additives in a ceramic mixture affects the entire technological process, decreases the firing temperature, and modifies the physicomechanical properties of the ceramics obtained. RF patent 2004110 describes an attempt to utilize a mixture containing 10 – 20% sludge from municipal sewage, clay, cinders, and technical carbon in production of ceramic articles.

Application of EAS in the silicate industry will make its possible not only to solve the problem of its utilization, but

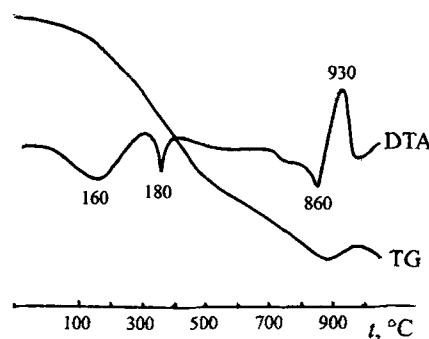


Fig. 2. Differential thermal analysis and thermogravimetric analysis curves DTA TG.

also free considerable areas of land suitable for agriculture. A decrease in the firing temperature will result in a decrease in power consumption.

However, before being used in the silicate industry, EAS has to be stabilized in order to prevent putrid processes and dehydrated. It is desirable to condition EAS before its dehydratation which will make it possible to improve the water-releasing properties of the sludge and reduce its specific resistance. The conditioning agent and its optimum quantity were selected for the Minsk aeration plant on the basis of laboratory research. The following reagents were tested in the experiment: 5% solution of  $\text{Al}_2(\text{SO}_4)_3$ , 5% solution of  $\text{FeCl}_3$ , 10% solution of  $\text{Ca}(\text{OH})_2$ , VPK-404 flocculent. Precipitation of the flocculent began only upon significant dilution of EAS, which contradicts the purpose of the experiment.

The most efficient coagulant was aluminum sulfate, and its coagulating capacity increases significantly on simultaneous addition of  $\text{Ca}(\text{OH})_2$  in the ratio of  $\text{Al}_2(\text{SO}_4)_3 : \text{Ca}(\text{OH})_2$  equal to 1 : 4. On introduction of different quantities of reagents in activated sludge samples, the optimum ratio was selected: 4 g  $\text{Al}_2(\text{SO}_4)_3$  and 16 g  $\text{Ca}(\text{OH})_2$  converted to dry matter per 1 liter of EAS. It is essential to note that it is possible simultaneously to stabilize and disinfect the activated sludge by adding lime. After stabilization, EAS does not represent any threat to operators, and it is suggested after dehydratation that the sludge be transported in closed containers from the Minsk aeration plant to Keramin company where it will be used as a burning out additive in production of brick.

In order to select the optimum composition and heat treatment procedure for samples containing EAS, bricks samples of different compositions were prepared, and their physicomechanical properties were investigated. Raw materials included clay from the Gaidukovskoe deposit, quartz sand, and EAS previously stabilized and dehydrated from the Minsk aeration plant.

Water was added when needed to the batch prepared, then the batch was cured for improvement of its molding ability and homogenization of its composition. Brick sam-

TABLE 1

Sample	Content of excess activated sludge				Content, g	
	by dry matter		for 85% moisture content		clay	sand
	g	%	g	%		
1	–	–	–	–	160.0	40
2	1.5	0.75	10	5	158.5	40
3	3.0	1.50	20	10	157.0	40
4	4.5	2.25	30	15	155.5	40
5	6.0	3.00	40	20	154.0	40
6	7.5	3.75	50	25	152.5	40
7	9.0	4.50	60	30	151.0	40
8	10.5	5.25	70	35	149.5	40
9	12.0	6.00	80	40	148.0	40
10	13.5	6.75	90	45	146.5	40
11	15.0	7.50	100	50	145.0	40

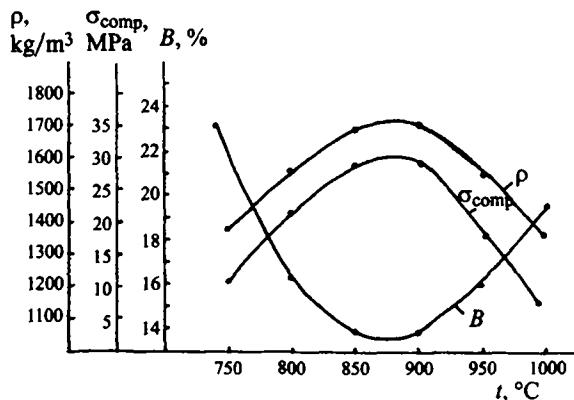


Fig. 3. Dependence of water absorption  $B$ , density  $\rho$ , and compressive strength  $\sigma_{\text{comp}}$  of samples of the optimum composition on firing temperature.

ples were molded in a metal mold  $30 \times 60 \times 15$  mm in size, dried naturally, and fired in an electric furnace.

It is seen from Fig. 2 that the properties of the samples deteriorate with an increase in the EAS content. At the same time, until the EAS content reaches 20% (by moist matter), the decrease in the sample parameters is insignificant. As the EAS amount reached 20%, the compressive strength decreased from 35.2 to 30.1 MPa, the density decreased from 1750 to 1680 kg/m<sup>3</sup>, and water absorption changed from 10 to 14%. A further increase in the sludge content caused sharp deterioration of all properties. Therefore, the composition containing 20% EAS (moist matter) was selected as the optimum composition, since the samples molded from this mixture, on one hand, have high physicomechanical characteristics, and on the other hand, allow for utilization of a substantial amount of waste.

The samples were fired with exposure at a temperature of 300 – 400°C, since according to differential thermal analysis (DTA) data (Fig. 2), the organic compound contained in the EAS is burned out at this temperature. The maximum firing temperature (860°C) was also selected based on DTA data and was supported by experimental data obtained for different temperature exposures.

According to the DTA data, moisture removal proceeds up to 160°C, which agrees with the decrease in weight on the thermogravimetric (TG) curve. On a further increase in the temperature, the organic compounds burn out, which is evidenced by the exothermic cupola-shaped maximum at 300 – 400°C. At the same time, carbonization of sludge and formation of carbon take place, and this is why the exothermic maximum is superimposed on an endothermic maximum at a temperature of 380°C. On burning out of organic ingredients, a further decrease in the weight is observed on the TG curve.

Activated sludge contains up to 30% inorganic compounds that begin decomposing with an increase in the temperature. Decomposition of carbonates with formation of oxides and CO<sub>2</sub> probably takes place at a temperature of 860°C. It corresponds to the endothermic effect on the DTA

curve and to a further decrease in weight on the TG curve due to evaporation of CO<sub>2</sub>. Next, as seen on the TG curve, the sludge weight increases, which is probably due to oxidation of the products of destruction of sludge mineral inclusions and the residue carbonated in previous stages.

The increase in the sample mass with an increase in the temperature generates internal stresses, the samples crack, and their properties deteriorate. That is why the temperature of 860°C was selected as the optimum maximum firing temperature. The validity of this choice of temperature is supported by the experimental data. Samples of the optimum composition (containing 20% EAS by moist matter) were fired at temperatures of 750, 800, 850, 900, 950, and 1000°C. It is seen from Fig. 3 that the optimum firing temperature is 850 – 900°C. When the temperature is below that specified above, the samples are underfired, and their parameters are not sufficiently high. At higher temperatures, the samples crack because of their weight increase, which results in deterioration of their properties.

Thus, the brick samples obtained which contain 20% EAS (moist matter) and are fired at temperatures of 850 – 900°C meet the requirements of GOST 530–95 (grade 300) and have the following properties: compressive strength of 30.2 MPa, cold resistance of 30 cycles, water absorption of 14%, apparent density of 1680 kg/m<sup>3</sup>, linear shrinkage of 7.8%.

An obligatory requirement that should be met in production of construction materials using any toxic waste (including EAS) is the environmental safety of the end product. Construction materials (brick, in our case) in service do not contact aggressive environments or food products. They experience only the action of atmospheric precipitation. Since any possible migration of toxic compounds (i.e. heavy metals in the case of using excess activated sludge from municipal sewage treatment works) into the environment is determined only by the degree of compound solubility, the quality of construction materials should guarantee that the toxic compound concentration in an extractant even in extreme conditions would not exceed the maximum permissible concentration of these chemicals in water. The maximum possible concentration of heavy metals in an extractant can arise in the case of acid rain effect on the construction material at high temperatures. That is why environmental safety monitoring of the samples obtained was carried out by extracting heavy metals from a crushed brick sample in acid medium at a temperature of 100°C for 5 h (taking into account GOST 10134–82 specifications) with subsequent atomic-absorption analysis of the extractant obtained.

Atomic-absorption analysis revealed that zinc, chrome, and nickel are absent in the extractant, and copper and cadmium are present as traces, which is significantly below the maximum permissible concentration. This is apparently related to the fact that heavy metals in high-temperature treatment are bound in high-strength and low-solubility compounds: silicates and aluminosilicates.

Thus, a mixture composition using excess activated sludge from municipal sewage treatment works and an optimum firing procedure were developed. The samples obtained have sufficiently high parameters, and their color does not differ from the traditional red color.

The appraisal of the environmental safety of the material developed revealed the absence of any dangerous effects on the environment.

The production of construction materials using excess activated sludge from municipal sewage treatment works is an efficient method for utilization of this type of waste, which makes it possible to expand raw material resources.

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